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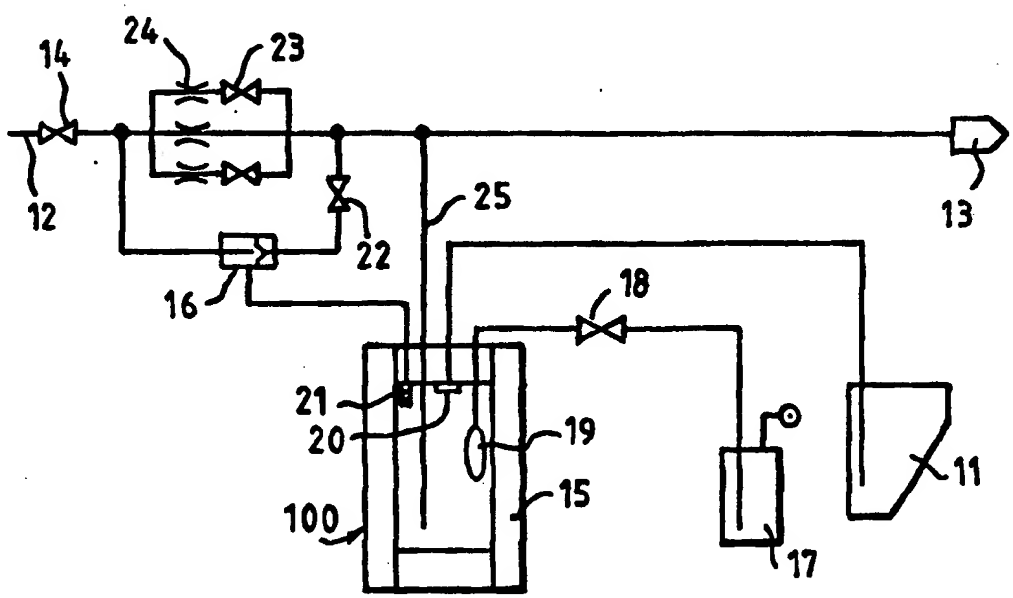
(54) Title: ABRASIVE MIXTURE SUPPLY SYSTEM



(57) Abstract

A conventional abrasive mixture pressurising system comprises a pressure vessel (15), a nozzle (13) connected to said compartment, an inlet (12) for fluid under pressure to drive the contents of the compartment to the nozzle and a supply of abrasive mixture. This is improved by dividing the pressure vessel interior by a flexible diaphragm (19) to define a compartment. This compartment can have its pressure controlled for various purposes - for example to create pressure surges for an immediate jet of abrasive mixture at the nozzle, or to suck in abrasive particles from a supply.

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ABRASIVE MIXTURE SUPPLY SYSTEM

An abrasive mixture contains abrasive particles in a carrier fluid. EP-A-0276219 shows cutting apparatus comprising a nozzle from which an abrasive mixture is ejected on to a workpiece, the abrasive mixture being formed by transporting abrasive particles from a hopper in a carrier fluid to a pressure vessel and then using additional carrier fluid to transport the mixture from the pressure vessel to the nozzle. The abrasive particles are moved from the abrasive particle supply in the hopper by passing carrier fluid through the hopper to transport the particle in suspension to a pressure vessel.

The pressure of the mixture at the nozzle is controlled by the pressure applied to the carrier fluid. At very high pressures, of the order of 200,000,000 Pascals, water is appreciably (by a factor of 10%) compressible, so some 5 litres of water will have to be introduced into a 50 litre pressure vessel to raise its pressure to this operating level and this introduction of water takes time. In intricate cutting operations such delays are not tolerable.

The present invention provides an abrasive mixture pressurising system comprising a pressure vessel, a flexible diaphragm within said pressure vessel defining a compartment within said pressure vessel, a supply of fluid under pressure, means for connecting said fluid supply to said compartment to drive the contents of the compartment to the nozzle, a supply of abrasive mixture connectible to the compartment, and means for controlling the pressure of fluid on the side of the diaphragm remote from the compartment to control the pressure within the compartment. The pressure may be controlled to control the introduction of abrasive mixture into the compartment from the supply, or it may be controlled by introducing a small quantity of liquid into a volume on the remote side of the diaphragm

from the compartment much smaller than the volume of the compartment so as to increase the pressure within the compartment at a much higher rate than could be achieved by introducing liquid directly into the compartment.

The connecting means preferably comprises a jet pump, whose high pressure inlet is connected to the fluid supply, whose low pressure inlet is connected to the compartment and whose outlet can be selectively closed. When the outlet is closed, the pump feeds the fluid from the supply to the compartment and this can be used to force the contents of the compartment to the nozzle, when the outlet is open the pump draws fluid from the compartment and forces it through the outlet and this can be used to drain the conduits of any abrasive material which had not been ejected form the nozzle.

Examples of the invention will now be described with reference to the accompanying drawings in which:

Figures 1-5 are diagrams of different abrasive mixture supply systems,

Figures 6,7 and 8 show modifications of parts of the above systems, and

Figure 9 is a diagram of another such system.

In Figure 1 an abrasive slurry is stored in a hopper 11, carrier fluid (water) is supplied under pressure at an inlet 12 and the apparatus causes an abrasive mixture under pressure to be fed from a nozzle 13. The apparatus also comprises a pressure vessel 15 and a jet pump 16. The hopper is connected to the pressure vessel by a transfer valve 20. A source of variable pressure 17 is connected through a valv 18 to a balloon diaphragm 19 within the pressure vessel 15. The fluid in the source 17 is separated from direct contact with the contents of the vessel 15 by th diaphragm 19.

The jet pump 16 has its high pressure inlet connected to the inlet 12 and its low pressure inlet connected to the interior of the pressure vessel 15 through a filter 21. The jet pump outlet is fed through a valve 22 to the nozzle 13. Valves 23 and restrictors 24 are connected in a by-pass to the jet pump 16 to control the concentration of the abrasive mixture at the nozzle 13. A conduit 25 connects the interior of the vessel 14 to the line from the inlet 12 to the nozzle 13.

In operation, abrasive slurry is drawn into the vessel 15 from the hopper 11 when the transfer valve 20 is open by cycling the pressure within the balloon diaphragm 19 by means of the source 17. The valve 20 is closed during increases in pressure within the diaphragm to prevent abrasive material being driven back to the supply 11. When sufficient slurry has been drawn into the vessel 14, the valve 18 is closed with the balloon left expanded and valve 20 is closed to prevent the slurry escaping back to the hopper.

The valve 22 is closed to stall the jet pump and fluid from the inlet 12 passes through the jet pump to the vessel 15, forcing abrasive mixture within the vessel 15 out through conduit 25 to the nozzle 13. This flow can be stopped by closing valve 14 in the fluid inlet 12 or opening the valve 22, but an emergency stop can be achieved by opening valve 18 to collapse the balloon 19 to reduce the pressure within the pressure vessel 15.

When the flow has stopped, some abrasive mixture will be left in the conduit 25; some will drain out, but with the jet pump running with valve 22 open, the pump 16 will operate in its designed mode of operation to draw liquid from the vessel 15 through the filter 21 and out through valve 22, thus draining the conduit 25 completely. The

filter 21 will prevent abrasive being drawn into the jet pump, thus causing wear of its components.

Figure 2 shows a modification of the apparatus of Figure 1 in which a second pressure vessel 31 is provided, in series with the pressure vessel 15. This enables the batch process provided by Figure 1 to be made into a continuous process. A conduit 32 leads from the vessel 15 to the second vessel 31. The outlet of the jet pump is connected through a valve 33 to the vessel 15, and the inlet 12 is also connected to the vessel 15 though a restrictor 34 and valve 35. When the vessel 15 is charged, valve 33 is opened (and 22 closed) to force abrasive mixture from vessel 15 to vessel 31. Valve 33 is then closed so that the flow from 12 through the jet pump forces the mixture out of vessel 31 through conduit 25. At the same time, vessel 15 is recharged from the hopper 11 using the pump 17 and balloon 19. The flow through 34 and 35 is used to repressurise vessel 15 to the same pressure as in vessel 31 after recharging with abrasive slurry.

In Figure 3 an alternative system for generating a varying pressure is shown, in the form of a piston 104 in the base of the pressure vessel 100, controlled by varying the pressures in lines 106 and 107. The piston 104 is separated from the abrasive mixture within the pressure vessel by a flexible diaphragm 102. In this figure the abrasive mixture is inside the diaphragm in contrast to Figure 1 where it was outside the diaphragm 19.

In the embodiment of Figure 3 there is only one pressure vessel; in the embodiment of Figure 4 there are two, each with a piston in the base for applying a varying pressure to the abrasive mixture within the respective vessel by means of the pressures applied in lines 106 and 107, and 108 and 109. The connections of the abrasive mixture

containers in each of the vessels in Figure 4 correspond to those already described with respect to Figure 2.

Yet another form of diaphragm for applying varying pressures to the contents of a pressure vessel while keeping those contents out of direct contact with the fluid used in applying the varying pressure is shown in Figure 5. A cylindrical diaphragm 302 lines the pressure vessel 300, keeping the contents inside and the pressure applying liquid outside the diaphragm. A similar diaphragm 303 is located in vessel 301. The differential pressure is varied by a pump 315 and valve system 308, 309. There is no jet pump in this and later figures, the carrier fluid flow being generated by pump 325 and valves 318-321 and restrictor 335.

In the arrangement of Fig. 5 a supply of abrasive particles, preferably in the form of a concentrated slurry, is provided in container 317 and fed through conduit 321 into the first pressure vessel 300 through a transfer valve 305 corresponding to the valve 20 described above and using the pressure control of the diaphragm 302 as described above in respect of the diaphragm 19. After introduction of the abrasive, the valve 305 is closed.

There is an inlet for carrier liquid at the bottom of the vessel 300, controlled by valve 319, carrier liquid being provided from a reservoir 327 through a filter 328 and a pump 325, under the control of two parallel arms, each arm containing a restrictor 335 and a valve 318. The pump has a twin intensifier which provides system flow of 5 litres/minute at about 250,000,000 Pascals in a phased sequence ensuring a better than 2% ripple. Flow rates are controlled by opening the valve 318 in one or both arms to utilise th corresponding restrictor(s). Flow of carrier liquid from the valves 318 can also be directed to a second pressure vessel 301 through valv 320 and there is a

connection 329 from the outlet of the first pressure vessel 300 to a second inlet of the second pressure vessel 301 controlled by valve 304 similar in construction to valve 305 of the pressure vessel 300. The outlet of the pressure vessel 300 leads through a discharge device 380 and a conduit 322 to a cutting nozzle 323.

In addition to the apparatus so far described, an additional input is provided in each pressure vessel 300, 301 for pressurising fluid from a hydraulic accumulator system on which a pump 315 pumps driving fluid to a hydraulic accumulator 310. A non-return valve 312 with a bypass valve 311 lead to a reservoir 314 for bleeding pressure from the pump 315 or refilling the pump system as required. When it is desired to force abrasive mixture from one pressure vessel without delay, the pump 325 may not be able to supply enough liquid to compensate for the compressibility of the water in the volume of the pressure vessel in the time available. Accordingly, pressurising fluid from the accumulator 310 is fed by the pump 315 through valve 309 (for vessel 300) and valve 308 (for vessel 301), the diaphragms 302, 303 protecting the hydraulic accumulator system from ingress of abrasive particles. The use of the hydraulic accumulator ensures that a plentiful supply of liquid under pressure is injected into the pressure vessel to counteract any effects of compressibility of the mixture so that an immediate response is obtained at the nozzle 323 to provide a high pressure cutting jet whose flow closely follows the operation of the hydraulic accumulator system. In addition the control of the pressure in conduit 306 when the valve 305 is open controls the introduction of abrasive particles from the supply 317.

In Figure 5, a bi-directional pump 313 with outlet control valve 328 is provided between the reservoir 314 and conduit 306 leading to the vessel 300. The pump 303 can be us d to

apply pressure cycles to the vessel 300 in order to assist the drawing in of abrasive mixture from the supply 317 and the forcing out of surplus carrier fluid once the abrasive particles have settled in the vessel 300.

In operation, the recharge pressure vessel 300 of Figure 5 is filled with pre-sieved abrasive from the supply 317 by cycling pump 313 in each direction with valves 305 and 328 open and valve 309 closed. This cycling draws abrasive into the vessel 300 while expelling surplus water. Valves 305 and 328 are then closed.

Valve 309 is now opened and liquid from the pump 315 pressurises the membrane 302. When the pressure in vessel 300 equalises with the pressure in vessel 301 valves 304 and 319 are opened and valve 320 closed. At the same time liquid from the pump 325 flows into the recharge vessel to carry the abrasive mixture under pressure from the membrane 302 from the recharge vessel 300 to the discharge vessel 301 through the conduit 352 and the valve 304. The pressure of mixture which may be discharged from the nozzle should not be affected since the same pressure is being applied to the membranes of both vessels during the transfer process.

With valves 309, 319, 320 and 328 shut, the abrasive mixture in the discharge vessel 301 is pressurised by liquid from pump 315 through valve 308 acting on the membrane 303.

Valve 320 opens so that the flow from 325 passes into the vessel 301 so that the mixture is forced from the vessel 301 to the nozzle 323 under the combined effects of carrier liquid from 325 and pressure applied from 315. The constrictions 335 and 321 allow some 90% of the flow from pump 325 to pass through 321 to join the mixture downstream of the conduit 322.

The pressure in the system can be relieved by depressurising the recharge vessel 300 first, with valves 308, 319 and 320 closed and valve 309 open, the pressure being vented through valve 311 or in the pump 315 itself. Valves 308 and 309 are now reversed and the pressure from the discharge vessel 301 relieved in the same way. If the pump 315 is used, it may need to be refilled with liquid through valve 312 before starting another pressurising cycle. In all these operations, the apparatus on the right hand side of Figure 5 is protected from abrasive particles by the membranes.

In place of the supply 317, a slurry container 331 can be loaded directly into the pressure vessel 300 and screwed in place. The container is provided with a special outlet adapted to cooperate with water from the valve 319 which flushes slurry out to vessel 301 through conduit 352. The flow control involving the parallel arms and valves 318 already described with reference to Fig. 5 could alternatively be located in a bypass conduit 337 as shown in Fig. 6, where alternative parallel arms each containing a valve and restrictor generally indicated by 335 are located in the bypass conduit 337 between the outlet of the valve 320 and the conduit 322. With this arrangement a further restrictor 336 is provided between the discharge device 380 and the conduit 322 and the restrictor 321 already described with reference to Fig. 5 is replaced by valve 334. This arrangement of restrictors is preferred for operating reasons, although the restrictors are closer to the abrasive particles since they are more likely to become blocked, the restrictors 335 and valves 318 being located in the supply of carrier fluid to the abrasive mixture and hence being less subject to contamination by abrasive particles. The provision of the restrictor 336 discourages abrasive blocking the nozzle conduit when abrasive flow is stopped.

The cylindrical membrane coaxial with the pressure vessel described above could be replaced by a closed tubular membrane 338 arranged parallel to the space from the axis of the pressure vessel as illustrated in Fig. 7. The membrane encloses an inlet tube 339 which may be porous and blanked at its end, providing support and additional sealing for the membrane on application of reverse pressure. This membrane is more similar t the balloon membranes of Figures 1 and 2.

In addition to the direct connection 352 between the vessels 300 and 301, a connection, between the respective pressurisation volumes on the side of the membranes remote from the abrasive mixture, containing a pump 350 and valve 351 in series may be provided, as shown in Figure 8. The pump 350 can be used to cycle pressurising liquid between the two vessels to assist the transfer of abrasive mixture through the direct connection 352. It will be noted that in this modification no carrier fluid connection is provided to the vessel 300 through a valve referenced 319 in other figures to assist the transfer between vessels 300 and 301.

Figure 9 shows an alternative configuration of the abrasive in liquid generating apparatus that can be used when rapid start up, stopping and pressure variation at nozzle 323 is not necessary. Abrasive is transferred from refill apparatus to the pressure vessel 300 by cycling pressure in conduit 355 connected to the exterior of tubular membrane 353 in vessel 354. The interior of membrane 353 is connected through valve 357 to the interior of membrane 338 (stiffer than membrane 353) in vessel 300. When vessel 300 is filled with abrasive, pressure is applied through conduit 355 to vessel 354 to displace fluid into membrane 338 at least equal to the compressibility volume of fluid in vessel 300 at operating conditions. When this is achieved valve 357 is closed and vessel 300 is pressurised

by opening valve 358 leading to the accumulator 346. Valves 304 and 319 are then opened to perform the transfer of abrasive from the vessel 300 to the vessel 301 as described above. On depressurisation, valves 358, 319 and 304 are closed before valve 357 is opened. In this embodiment the membrane 338 serves to isolate the abrasive from the pressurising source 355, but not from the accumulator 346.

CLAIMS

1. An abrasive mixture pressurising system comprising a pressure vessel, a flexible diaphragm within said pressure vessel defining a compartment within said pressure vessel, a nozzle connected to said compartment, an inlet for fluid under pressure, means for connecting said fluid inlet to said compartment to drive the contents of the compartment to the nozzle, a supply of abrasive mixture connectible to the compartment, and means for controlling the pressure of fluid on the side of the diaphragm remote from the compartment to control the pressure within the compartment.

2. A system as claimed in claim 1 wherein the connecting means comprises a jet pump having a high pressure inlet connected to said fluid supply, a low pressure inlet connected to said compartment and a closable outlet.

3. A system as claimed in claim 1 or claim 2 wherein the flexible diaphragm comprises a closed resilient container and the pressure varying means comprises means for introducing fluid into and withdrawing fluid from the resilient container.

4. A system as claimed in claim 1 or claim 2 wherein the flexible diaphragm comprises an annular diaphragm dividing the pressure vessel into a central compartment and an encircling annular compartment.

5. A system as claimed in any one of the preceding claims comprising a conduit between the fluid inlet and the nozzle by-passing the pressure vessel, and means to control the flow in said conduit.

6. A system as claimed in claim 5 comprising a restrictor in the outlet of the pressure vessel upstream of its junction with said conduit.

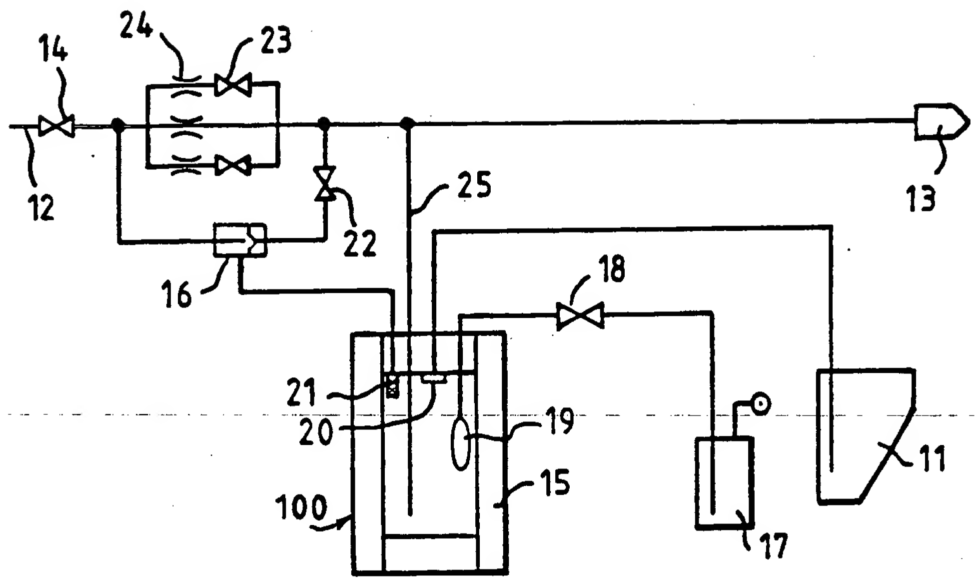
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FIG.1

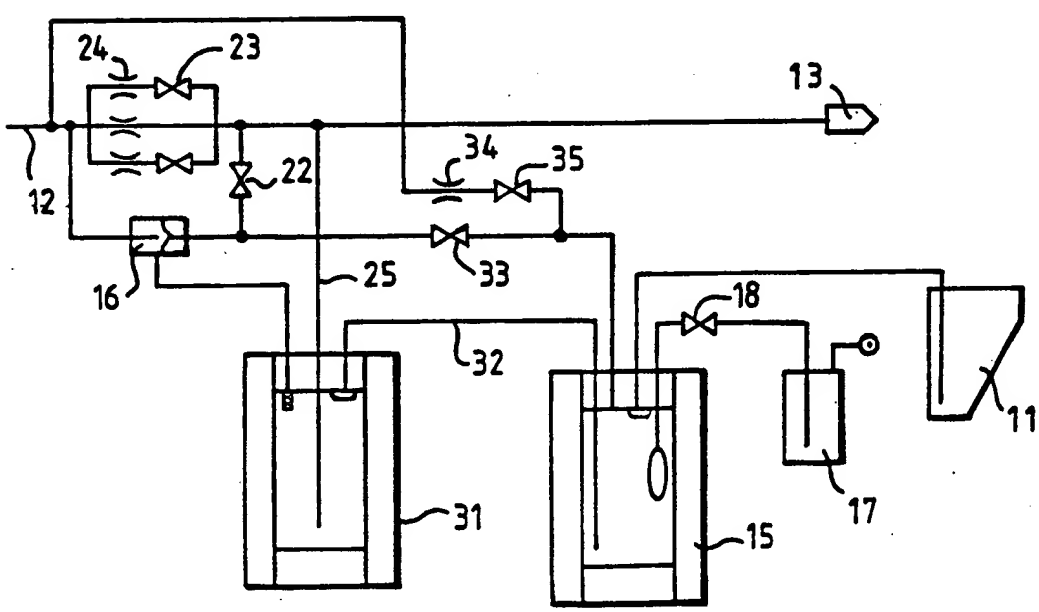
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FIG.2

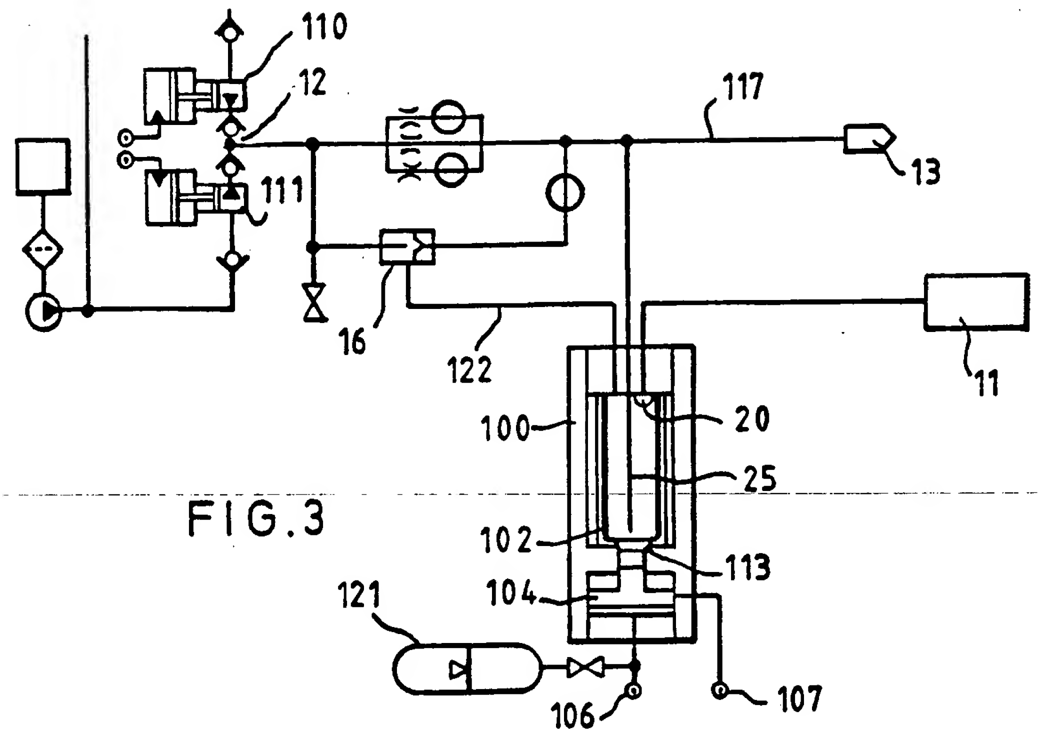
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FIG.3

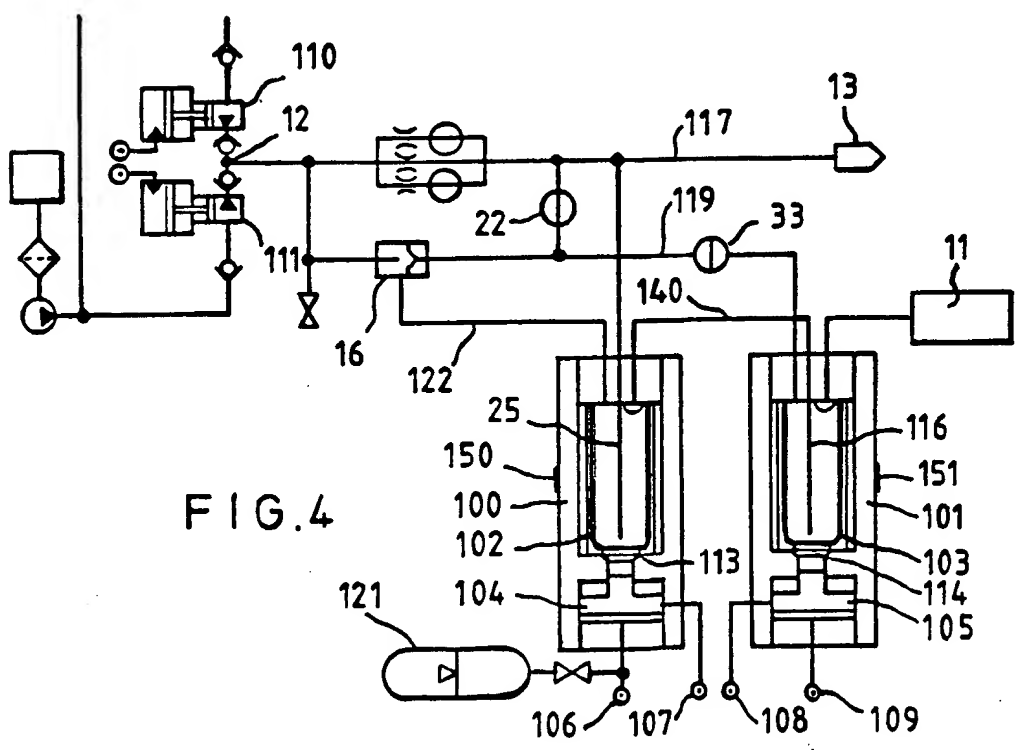
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FIG.4

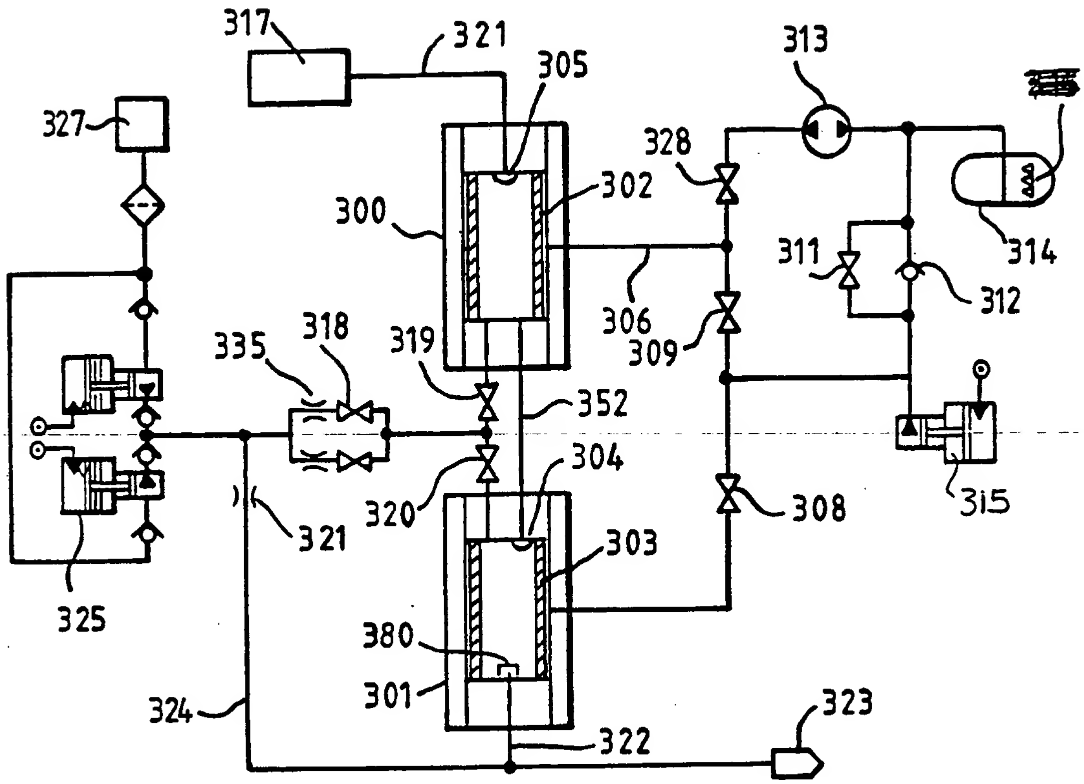
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FIG. 5

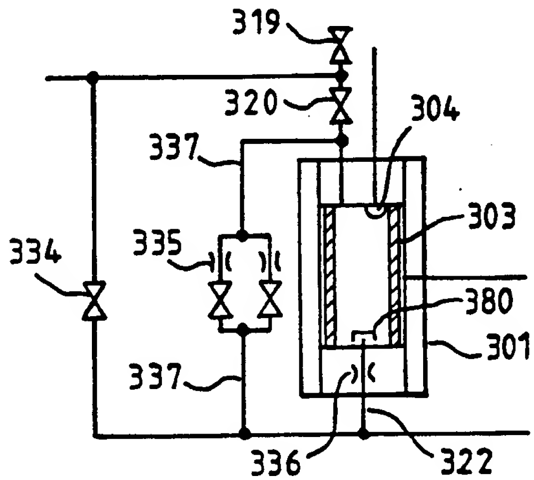
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FIG. 6

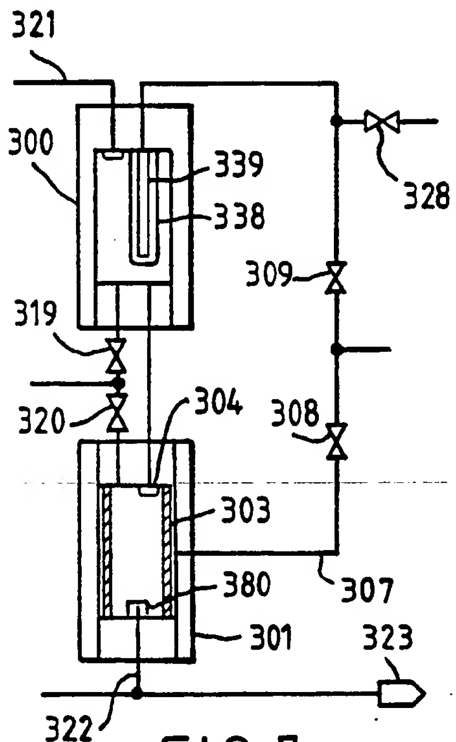

FIG.7

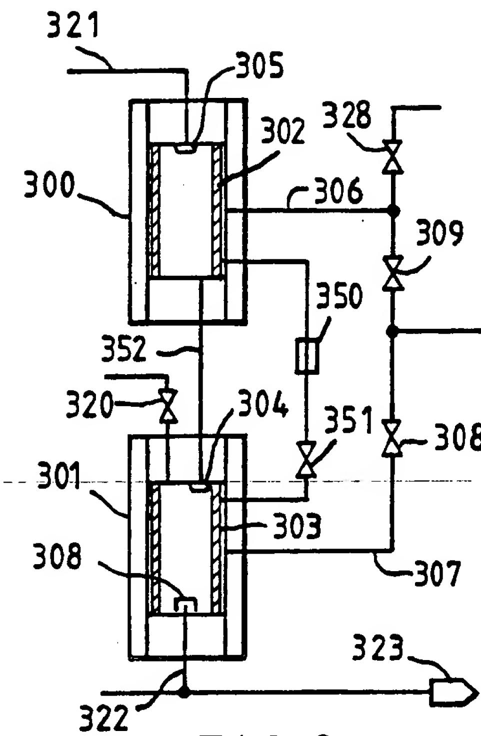

FIG.8

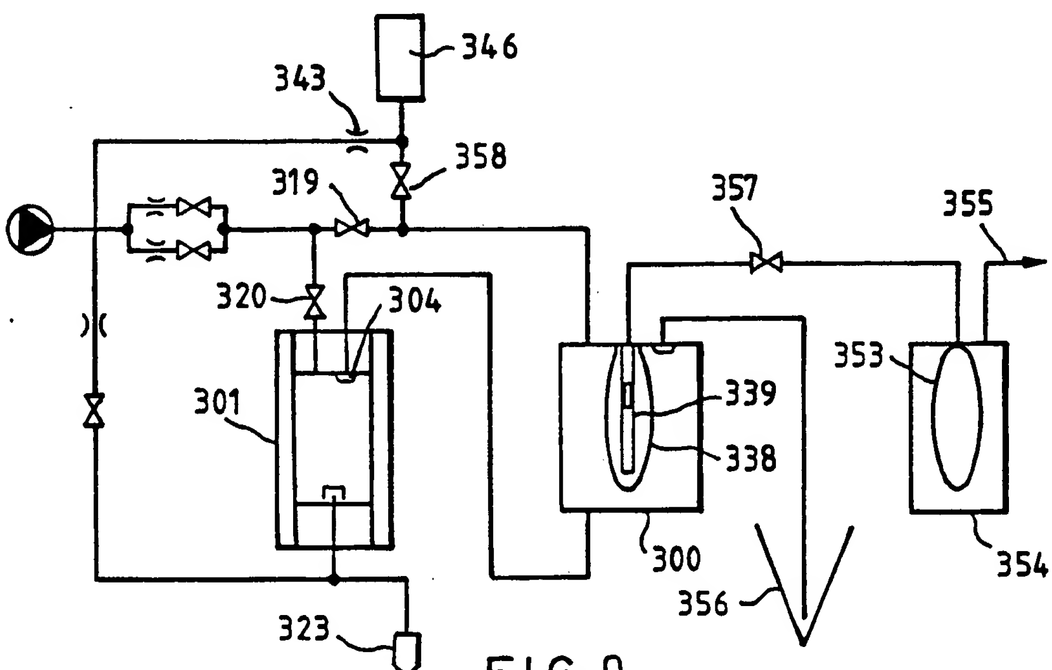

FIG.9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/00979

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24C1/04 B24C7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24C F15B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,3 062 153 (W.A.LOSEY) 6 November 1962 see the whole document ---	1,3
A	WO,A,87 02290 (THE BRITISH HYDROMECHANICS RESEARCH ASSOCIATION) 23 April 1987 cited in the application see page 6, last paragraph - page 8, line 7 see page 10, line 8-28; figures 1,5 ---	1,5
A	EP,A,0 322 485 (INGERSOLL-RAND COMPANY) 5 July 1989 see the whole document ---	2
A	US,A,5 184 434 (HOLLINGER ET AL.) 9 February 1993 ---	
A	FR,A,1 196 124 (TRICHOT) 22 January 1959 -----	

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1

Date of the actual completion of the international search	Date of mailing of the international search report
7 August 1995	18.08.1995

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-3062153	06-11-62	NONE		
WO-A-8702290	23-04-87	AU-B-	591529	07-12-89
		AU-A-	6475986	05-05-87
		EP-A,B	0276219	03-08-88
		JP-T-	63501489	09-06-88
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